Dr. Jackie Puhl of the U.S. Olympic Committee's Sports Medicine Division readies Cathy Hearn for testing, assisted by Paul Grabow, 1981 C2 Bronze Medalist.

SECTION II: THE BODY

PHYSIOLOGICAL PRINCIPLES

Whitewater slalom is a mixture of aerobic (with oxygen) and anaerobic (without oxygen) work. I believe that at the elite levels, however, the anaerobic component has been neglected or at least not emphasized enough. Indeed, I think the greatest change in slalom over the last decade is that it has become more anaerobic. For some top paddlers it may be 70% anaerobic. Various rules changes which have minimized penalties, and better boats, have sped up the sport considerably and in order to win nowadays you have to be very fast. To develop speed, you have to develop anaerobic abilities.

Thus, to train properly for modern slalom, it is necessary to do a large amount of anaerobic or high intensity work which stresses the muscles' ability to function with high levels of lactic acid. My view contrasts with the traditional view that slalom is primarily an aerobic event and that the proper training for it involves a lower intensity but high volume of training (aerobic work).

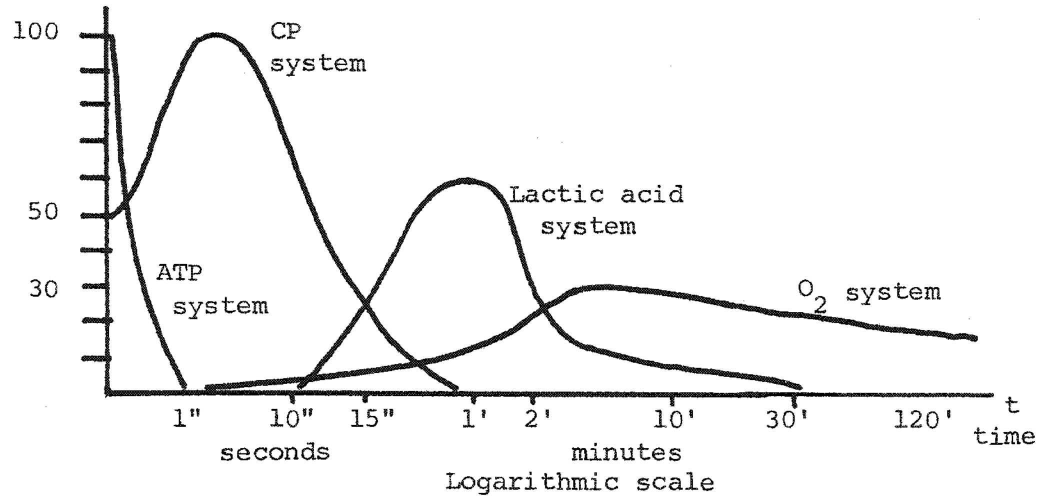
Having said this, however, I must caution the reader: High intensity training without proper technique will not bring about success. Indeed, for most slalom athletes, technique is the area of greatest weakness. Thus, except for a very few of the world's top slalomists, physiological considerations should never replace technique considerations. The physiological principles should be applied to gate workouts so that technique and conditioning can advance at the same time. This means the work should be done in gates, preferably whitewater gates, not in the weight room, or on the running track.

Three Energy Systems

Physiologically speaking, the body produces energy from three different systems, with the preponderance at any given time being on one of the systems. All three systems are genetic, that is, the maximum potential is determined at birth, and the percent of that potential you reach is determined by hard training. Exactly when each system comes into play is determined by a combination of the intensity, duration of the exercise, and the duration of the rest period. Furthermore, the employment of the systems is not purely sequential and they operate to some extent at the same time. However, for purposes of clarity, I treat them separately here.

The three systems are: the ATP-CP system, in which you operate at maximum intensity for a short period (less than about 15 seconds); the lactic acid system, in which you operate at very high intensity for up to about 180 seconds and thus produce lactic acid; and the 02 system, in which you operate at a lower intensity and thus can do so for much longer periods.

The graph below represents the three systems and the variables of duration and intensity of exercise. To represent intensity, ASSUME YOU ARE GOING AT AN ALL-OUT SPRINT THE ENTIRE TIME. This might occur, for example, if you attempted an all-out 500 meter sprint in a slalom boat. It should be borne in mind, of course, that a slalom race is not exactly like this, because it has stop-go elements -- places where you increase and decrease the intensity of effort. Nonetheless, this graph gives an idea of what we are talking about:

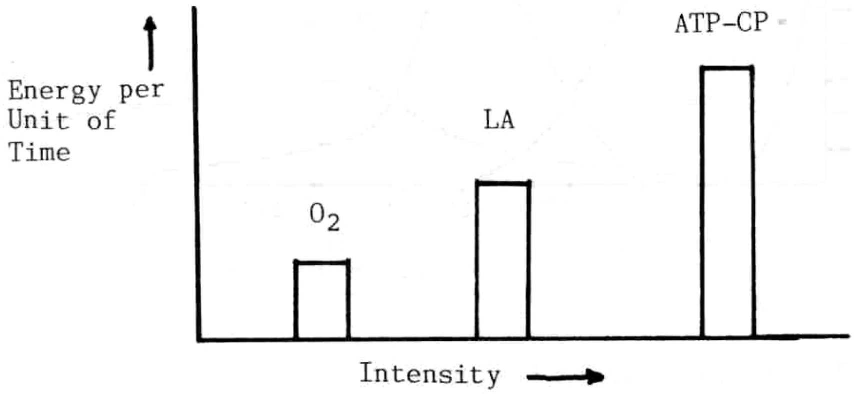


ATP-CP SYSTEM: This system has several names, each descriptive of some of its characteristics. It is sometimes called the anaerobic alactic system because while using it, you do not supply your oxygen needs from air taken in during exercise. In fact, you may be holding your breath during the whole duration of this system; for example, a 50 meter sprint in a slalom boat. Yet the exercise does not go on long enough for you to produce perceptible amounts of lactic acid in the bloodstream (thus it is alactic). Sometimes the system is simply called the fast energy system because it is the fastest source of energy.

Adenosine triphosphate (ATP) is a compound necessary for muscular contraction to occur. Limited amounts of ATP are stored in the muscles and a very quick contraction, lasting a fraction of a second, uses it all up. For any exercise lasting longer than this, another compound, creatine phosphate (CP), must be used. Creatine phosphate quickly breaks down to provide more energy, thus allowing a somewhat more prolonged muscular activity. However, the combined ATP-CP system is depleted after about 15 seconds. The 100 yard dash is the classic example of an event relying on the ATP-CP system. I believe that certain parts of a slalom course requiring short bursts of energy at maximum intensity, such as certain upstreams, reverses, and sprints between gates, also rely heavily on this system.

However, there are some important points to remember about how the ATP-CP system works. Since it is exhausted very quickly, its use for sharp bursts of energy is likely to occur only on the top few gates of a slalom course. A classic example would be a hard reverse gate or upstream at gate 2 or gate 3. Nevertheless, it is possible that on a course with one "make or break move", a boater might paddle quite slowly up to that point and use the ATP-CP system to make the move. In this case, although the ATP-CP system can be relied on only for one or two bursts, those bursts may come at crucial times on the course and lead to the saving of a great deal of time.

The following graph depicts the fact that the more intense the work effort is, the greater the energy per unit of time with the anaerobic systems (the ATP-CP and lactic acid systems).



In an untrained person, ATP-CP is exhausted in about 8 seconds. But through proper training, it can be made to last a few seconds longer. Specific training causes a larger storage of ATP-CP in the muscles. It does not, however, provide any more ability to replenish the supply of ATP-CP during the race, say in places where only steering is needed and therefore little real exertion for a few seconds. A possible exception to this might be in a team race, where you had to wait for the other boats for a bit. Depending upon how long the rest was, there could be a partial replenishment of ATP-CP stores.

Proper training for maximizing the ATP-CP system would be very short courses, lasting about 10 seconds or less, done at maximum intensity. These could be done in gates, but they don't have to be. Short sprints on flatwater are another way. I like to do them on gates, however, because besides working the ATP-CP system, there is familiarization with gate techniques at very high speeds as well.

It doesn't take very long to build up the ATP-CP system -- 2-3 weeks at most. But while ATP-CP is built up relatively quickly, it is also lost quickly through disuse. Since it doesn't take long to develop the ATP-CP system, it is usually the last of the three energy systems to be developed with emphasis on it coming only in the few weeks before the major race. Since the other two systems take longer to develop, work on them is typically begun earlier in the yearly training. During the period of emphasis, the ATP-CP system may be worked daily, but more likely, it would be combined with other work (LA system), and targeted exclusively only every other day.

LACTIC ACID SYSTEM: Sometimes this system is called the anaerobic lactic system because when using it, you are operating anaerobically and you do it long enough to produce lactic acid. Once ATP is depleted through the ATP-CP system, described above, the body supplies ATP through another energy system, the lactic acid system. In this, the intensity of the work is very high (but not maximal) and oxygen debt is incurred while breaking down glycogen to supply ATP. However, the breaking down of glycogen in the absence of oxygen produces a waste substance called lactic acid which inhibits muscular contraction as it accumulates in the exercising muscles. It is lactic acid which causes the burning sensation in muscles and later stiffness. Running a full length slalom course as fast as you can go makes heavy demands upon the LA system, in my opinion. The ability to function with a high lactic acid build-up and to dissipate it quickly in rest periods following exertion is also trainable. Intense courses of between 30-120 seconds is one good way of doing this.

It takes about 6-8 weeks of concentrated effort to build up the lactic acid system. Thus, this system is the next to last one that the athlete should concentrate on and he can start it from 8 to 10 weeks before the big race. During this period, the LA system should be worked about 3-4 times a week. Working the LA system 1-2 times a week is enough for maintenance but not for improvement.

A moment ago, I mentioned that the LA system is used in breaking down glycogen in the absence of oxygen. It is worth pointing out here that carbohydrates are the prime source of glycogen. During normal physical activity, glycogen is formed by, and largely stored in, the liver and to a lesser extent in muscles, being converted into glucose and released as needed. The best source of carbohydrates are complex carbohydrates such as vegetables and fruits, not simple carbohydrates, such as pure sugar or junk food.

The higher the glucose levels in an athlete's body, the longer he can exercise. The initial supply of glycogen lasts about 80 minutes. After two hours, additional glycogen has to be stored or added. A highly trained athlete has a large capacity to store glycogen intramuscularly. It takes up to 48 hours to replenish liver glycogen, but only a few hours to replenish muscle glycogen. Thus, in a slalom workout lasting, say an hour, it would not be likely that the athlete would suffer significant liver glycogen depletion, although he would suffer depletion of muscle glycogen. Therefore, he would be able to have two or more workouts a day without adverse consequences. But if the workouts were very long ones, say 2 hours, there could well be a significant depletion of liver glycogen and the athlete would need about 48 hours to replenish his stores. This is why some athletes follow the hard day, easy day cycle in training.

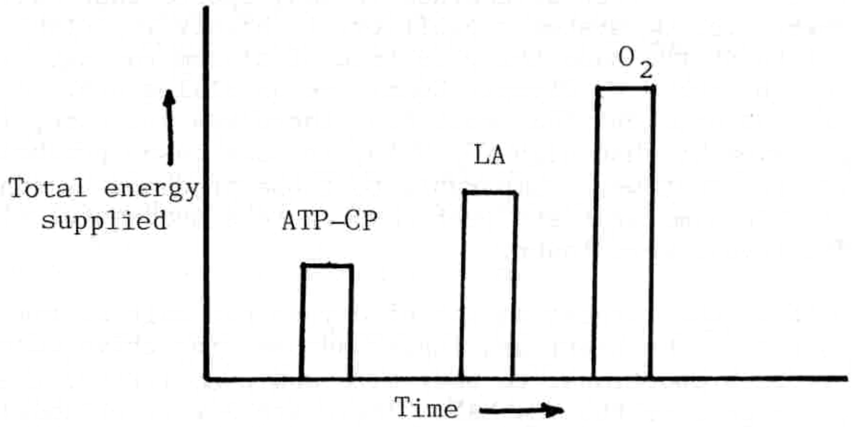
Many people think that it is not necessary to worry about glycogen stores in slalom (as opposed to downriver), because a slalom race does not last very long. But in my opinion, the application of these physiological precepts comes more in training sessions, which may last a long time, and during major competitions that go on for several days (team selection trials; World Championships). The ability to support a high training load will dictate how much training time you get. The amount of training time will eventually determine how good you get -- and consequently how well you do on race day. Races that go on for many days also wear you down and the athlete who maintains his energy levels throughout the whole period will have a large advantage.

0_2 SYSTEM: This is sometimes called the aerobic system, for unlike the other two systems, it is not anaerobic and in using it, you supply your oxygen needs from the outside air during exertion. In the 02 system, glycogen is broken down into ATP but this time in the presence of oxygen and thus use of this system does not cause the build-up of lactic acid. However, lactic acid may well have been built up in previous work bouts because the lactic acid system may have been used first. But in this case, transferring from the LA system to the 02 system will allow lactic acid to dissipate somewhat. Furthermore, the 02 system can actually use lactic acid as a fuel, similar to glycogen.

A full length slalom course uses the 02 system to a large extent. Even though a large component of modern slalom is anaerobic (probably more than 50% for many top slalomists), having a good aerobic capability allows you to paddle longer aerobically (i.e., with less effort), so that your total time over the course may be faster.

Having a good 0_2 system will also help an athlete get through a long workout consisting largely of anaerobic segments. The sheer duration of the workout taxes his aerobic powers. Thus, his ability to do a lot of anaerobic work might be lessened because of a poor aerobic capacity. This is one reason it is thought best to begin a year-long cycle of training with emphasis on the 02 system: A good 0_2 system is necessary to support the high levels of intense training to come.

This situation is depicted in the following graph which shows that the longer the work continues, the greater proportion of the total energy supplied comes from the 02 system.



But the real reason it is thought best to begin the yearly training cycle with emphasis on the 02 system is because it takes longer to develop significantly than the other three -- 3-4 months. During this period of 3-4 months, the 02 system should be worked 4-6 times a week. Traditional literature says that this can be done through general training, such as swimming, cross-country skiing, and running (in that order of preference). My own personal belief, however, is that it should be done primarily in the boat, in gates (as opposed to the downriver boat), because this is the most specific for slalom. It takes only 2-3 times a week to maintain the 02 system.

I have to say that I have some other differences with traditional theory, too. As I have pointed out, the common belief is that the 02 system should be developed first, then the LA system and finally the ATP-CP system -- as though they had to be done in that order. I don't think the order matters as long as they are all fully developed by the time the peak is desired. In other words, you can put a lot of emphasis on the LA system during the time that traditional theory says you should be focusing almost exclusively on the 02 system. From personal observation of many World Champions' training, I believe that there is aerobic value in a large volume of anaerobic training. I am also told that there is some research that supports this. It indicates that improvements in both aerobic and anaerobic capabilities are possible with high intensity interval training -- 2-3 minute pieces at 80-90% intensity. The point: Make sure you do enough LA system development and this is probably more than traditional literature would have you believe is necessary. A subsidiary argument for more anaerobic training is that it familiarizes the boater with gate technique at high speed, speeds somewhat higher than race pace. This is necessary because in order to go fast in the race, you have to practice it in training.

Measurements of Aerobic and Anaerobic Power

VO2 MAX. VO2 MAX means literally the volume of maximum oxygen consumption. It has been determined in many sports that maximal aerobic power, i.e. 02 system capability, is highly important to success. I think the same thing is true of slalom racing. In tests administered by the U.S. Olympic Committee on slalom athletes I have coached, it was apparent that most (but there was one exception) of the elite slalomists had high VO2 MAXs, in some cases producing values with their arms that were comparable to those produced by runners with their legs. In similar tests performed on less successful slalomists, the VO_2 MAX levels were lower.

VO_2 MAX is the largest amount of oxygen per unit of time that can be transported by the heart and lungs and used in active muscle tissue. It is proportional to body size and muscularity; the greater the size, the greater the VO_2 MAX. There are 2 ways of looking at VO_2 MAX. It can be expressed in liters of air per minute (L/Min) or related to body weight and expressed as milliliters per kilogram of body weight per minute (ML/Kg/Min). The key to determining which measurement is most appropriate is whether the athlete supports his own weight or not. A runner supports his own weight so ML/Kg/Min is the value of interest to him. An oarsman sitting in a racing shell does not, so he is interested in L/Min. Since a slalom paddler is sitting in a boat also, it would seem that L/Min is the value most appropriate to his sport, but since there has always been some dispute about this, I always like to look at both values.

The test for VO2 MAX is administered by increasing in stages the amount of exercise the athlete is forced to do while collecting the actual amount of expired gases. By subtracting this value from the surrounding air, the oxygen consumed is calculated. The MAX occurs when the next higher workload is not associated with increased consumption, indicating that further effort is accomplished anaerobically (without oxygen).

VO_2 MAX has traditionally been measured by having the athlete run on a treadmill. Some years ago, however, I found out that unless the form of exercise in the test is specific to slalom, the results are not very meaningful. Thus, in recent years, I have had these tests done on an arm ergometer, fashioned from a bicycle. The athlete pedals" with his arms, thus simulating the paddling movements.

In October 1982, I was able to interest the U.S. Olympic Committee in measuring VO_2 MAX and other things in the most specific form of exercise of all, a simulated slalom race on our training course. Among those tested were World Champions Cathy Hearn, Elizabeth Hayman, Fritz Haller, Steve and Michael Garvis, David Hearn, Jon Lugbill, Bob Robison, and fifth place finisher at Jonquiere, Chris

McCormick. Two sets of tests were done. First on dry land, the paddler was tested on the arm ergometer, where $V0_2$ MAX, heart rate and blood lactate levels were measured. Then, after appropriate rest, the paddlers were tested again, this time in the boat on a slalom course consisting of 37 gates and having a running time of 269 seconds for the best kayak. Expired air was collected in a bag taped to the stern deck of the boat. Finally, in some cases, heart rate was measured throughout the course through a radio transmitter attached to the paddler's torso. The heart rates were transmitted only sporadically, however, and thus were discontinued after a few paddlers had been tested, but one pattern did appear to emerge: heart rate was elevated the most on upstream gates, thus seeming to indicate that upstream gates require the greatest amount of work.

There were several interesting findings regarding $V0_2$ MAX. Absolute values (L/Min) were quite high for ergometer work. When compared to running $V0_2$ MAX values, the ergometer values were similar to moderately trained men and women. This is unusual, since normally the greater the muscle mass used (legs compared to arms), the greater the $V0_2$ MAX.

Looking at $V0_2$ MAX related to body weight (ML/Kg/Min), the values were also good. With the exception of Steve and Michael Garvis, World Champions in C2, the VO_2 MAX values ranged from 54-69 ML/Kg/Min, with four men in the 60's. Male rowers, using a larger muscle mass (legs and back in addition to arms), have been measured at about 63 ML/Kg/Min. The two World Champion women tested, Cathy Hearn and Elizabeth Hayman, had values of 54-55 ML/Kg/Min which compare favorably with running values obtained by endurance trained college women cross country runners.

But do paddlers use a large percent of their $V0_2$ MAX in the boat during a slalom run? If they don't, then having a high VO_2 MAX might not be all that important. But if they do use most of their $V0_2$ MAX in a race, building a high aerobic capability would be very important to success.

The answer is that top slalomists do use a large percent of their VO_2 MAX in the boat. The percent of ergometer-measured VO_2 MAX used during the on-the-water tests conducted by the Olympic Committee ranged from 63% (David Hearn) to 115% (Steve Garvis). The group mean was 83.1%. Those using over 75% of their ergometer VO_2 MAX on the water are probably typical. All of this seems to indicate that a high $V0_2$ MAX is one indicator of an elite slalomist. All of the elite slalomists tested, except the Garvis brothers, had high $V0_2$ MAXs, although many other non-elite paddlers also had high ones.

The Olympic Committee concluded its remarks on slalomists' V02 MAX with this statement:

The improvement of aerobic capacity through endurance training should be of value to performance because the higher the aerobic capacity, the less one needs to rely on the anaerobic metabolism during strenuous but sub-maximal exercise. This would delay lactic acid accumulation and delay fatigue.

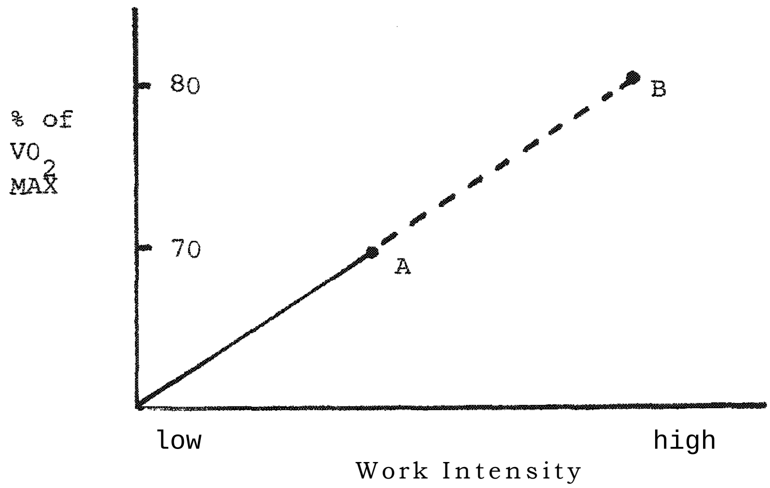
If (paddlers) can improve their VO_2 MAX (aerobic capacity), they will be able to do a given amount of sub-maximal work with greater ease, i.e. lower physiological stress, as shown by lower blood lactate at the sub-maximal load.

A suggestion for training would be some bouts of 5, 10, and 20 minutes performed 4-5 times a week. Obviously arm work would be best. However, other upper body work using endurance weight training or circuit training would be useful.

ANAEROBIC THRESHOLD

At a certain point, a paddler approaching his $V0_2$ MAX starts to lapse into an anaerobic state. The point at which this occurs is called the anaerobic threshold. It starts to occur at about 70% of VO_2 MAX in the average untrained individual but at a higher percentage in the well-trained person.

The following graph depicts the situation:



One paddler reaches his anaerobic threshold at point A. He can continue to do work but from here on, it will be in an anaerobic state (and therefore less efficient). The paddler reaching his anaerobic threshold at point B can do more work than A in an aerobic state, which means that B can do the extra work easier than A. It could be true that A may be able to function better than B anaerobically and may even be able to beat B, but he will have to work harder than B to do so and thus it is less likely that A will be able to beat B.

Once a paddler is in an anaerobic state, it is important to know how long he can stay there, and how anaerobically he can function. The method of measuring this is to measure the amount of lactate present in the blood. It is typically reported in milligrams percent, which is simply the amount of lactate per unit of blood, expressed as a percentage.

The blood should not be drawn immediately after exertion because peak levels of lactate are usually reached 3-5 minutes after exertion. It takes that long for the lactate to be washed out of the muscles and into the blood stream. The higher the lactate levels, the more anaerobically the paddler has gone.

In the tests administered by the Olympic Committee, blood lactate levels were measured both after the ergometer test and after the on-the-water test. On the ergometer test lactate levels were nearly all acceptably high. Values over 100% are high, values in the 90's are good, values in the 80's are acceptable. The range on the test was 46.3 to 121.3. Only one paddler was below 80%, and for this person, it was recommended that more anaerobic work be done.

Once again, it was found that the paddlers utilized a high percent of their maximum anaerobic capacity in the boat, about 83% of it, thus indicating that a higher anaerobic capacity would be useful in a slalom race. As with the $V0_2$ MAX tests, the lactate tests seemed to show that high lactate levels are another indicator of an elite slalomist. In other tests administered to less successful slalomists, lower lactate levels were found.

In conclusion, the entire battery of tests administered by the U.S. Olympic Committee seemed to show that slalom places heavy stress on both the aerobic and anaerobic metabolisms. It isn't necessarily a question of one being more important than the other, however. They are both very important and to be at the top in the sport you probably have to have high values in both.

Interval Training

The purpose of this section is to supply the reader with enough knowledge of interval training principles so that he can devise ways to apply them to whitewater gates and thus achieve maximally effective workouts.

The key to interval training is that intermittent work -- bouts of exertion followed by rest -- guarantees that the work will be done at maximum intensity, which is necessary for maximum improvement in the energy system in question. This is contrasted to steady-state work in which there is no rest interval, only one long work interval, and thus the intensity level is of necessity much lower.

Intermittent work also improves heart stroke volume. Stroke volume is one of the two key factors in determining the amount of blood pumped by the heart (the other is heart rate). It is the highest not during the work interval, but in the rest period after it. The higher the stroke volume, the more blood pumped by the heart, and thus the more oxygen that is transported to the exercising muscles. With interval training, there are many recovery periods, and thus stroke volume reaches its highest level many times during the workout. This contrasts with steady-state paddling in which there is only one rest interval (at the end). Achieving maximum stroke volume many times a workout, over many weeks of interval training provides a much greater stimulus for improving stroke volume.

Interrelationship of Five Variables

Interval training involves the interrelationship of five variables:

* Duration of work interval
* Intensity of work interval
* Duration and type of rest interval
* Number of repetitions/sets
* Number of interval workouts per week

Changing any one of these variables changes the nature of the interval workout. To devise his own workout, the boater and/or his coach must know how to manipulate them. A discussion of the variables and how they interrelate follows.

DURATION OF WORK INTERVAL: As we can see from the preceding discussion of the three energy systems, the duration of the work interval has an effect on which energy system is emphasized. To target the ATP-CP system, short bouts of intense effort are best. In slalom terms, this would be all-out 15 second courses, followed by 45-60 seconds of rest. This will allow the ATP-CP system to be used over and over again at maximum intensity (as long as the rest period is right -- see below), which is ideal for stimulating it adequately. The short work interval prevents the onset of fatigue by preventing the build-up of lactic acid. A long rest allows ATP-CP stores to be replenished.

To emphasize the Lactic Acid system, intense slalom courses of 40-120 seconds are good (10-20 gates). This trains the body to operate with high levels of lactic acid (particularly with long work intervals).

To emphasize the 02 system, an even longer work interval of, say, 8 minutes (or more), about 100 gates, is good. Since the work goes on for some time, it is aerobic. These kinds of workouts are best done as loops where the boater repeats the gates over and over again. While it is possible to do the workout if one actually has a course of 100 gates stretched out one after the other, it usually takes too long to memorize the course, and thus it is impractical. Another problem is keeping the rest period short enough.

A better way is to set up a ten-gate course, say, and repeat it over and over again, perhaps taking lap times on each loop. Loops, I have found, also happen to be an excellent way to practice technique because the boater does the same move over and over again, thus perfecting it. Furthermore, loops work well on whitewater rivers where there is really only one good rapid. The loop can be set up on the rapid and then a long continuous stretch of whitewater is not necessary in order to be on good water for the whole workout.

INTENSITY OF WORK INTERVAL: In order to achieve maximum effectiveness in interval training, the work intervals must be done with sufficient intensity. Heart rate can be used as one guide. The following is an intensity scale.

Scale Of Intensity	Percent Of Maximum Heart Rate
Low	30-40%
Light	50-64
Medium	65-74
High	75-84
Sub-Maximum	85-94
Maximum	95-100

To target the ATP-CP system the work interval has to be done at maximum intensity. I have found that the best way to do this in slalom is on courses consisting of 3-5 gates. The gates should be spaced apart reasonably, or perhaps a bit more than usual. They should not be minimum width or minimum height off the water. The moves should be free-flowing and natural -- no awkward turns. An example: two forward gates, an upstream, another forward, and a final reverse. With this kind of course, the boater can go at absolute maximum. More complex or tricky courses cause him to slow down too much to work the ATP-CP system. Those kinds of courses are best for developing good technique.

To emphasize the LA system, the intensity of the work interval should be sub-maximal. Here any kind of course will do. Some tight moves and some wide open ones are good.

To emphasize the 02 system, the intensity should be high. I think this is an important point. Many people think that very low intensity work is fine for developing the 02 system. While there may be some 02 development at very low intensity, I think there is much more rapid improvement if the intensity is high.

While heart rate may be the best scientific indicator of sufficient intensity, a more practical way is to use the stopwatch: Simply race boaters against each other for time and penalties. The boaters' competitiveness stimulates them to more intense exertions. Many times I have seen someone who thought he was working hard, work significantly harder once a rival started doing the same course. I believe for the vast majority of people, these competitive workouts are the best, most efficient way to train. There are exceptions to this, however, and competitive workouts cannot be used all the time. Still, in my experience, if approached properly, they are not only the most efficient, they are also the most fun.

If the boater can't race other boaters, or doesn't want to, he should at least time himself. By attempting to get the same times or increasingly faster ones on each interval, the boater ensures the necessary intensity level. Digital wristwatch/stopwatches work best for this, and many top boaters prefer the ones made by Casio.

Only on very short courses (used for ATP-CP development), is it impossible to time yourself accurately enough. On these courses, tenths of seconds determine whether you are going at absolute maximum or something less than that. Therefore someone timing from the shore is necessary for this work. Another option is to have boaters time each other.

REST INTERVAL: In a general sense the rest interval simply allows the body to recharge so that another intense interval can be attempted.

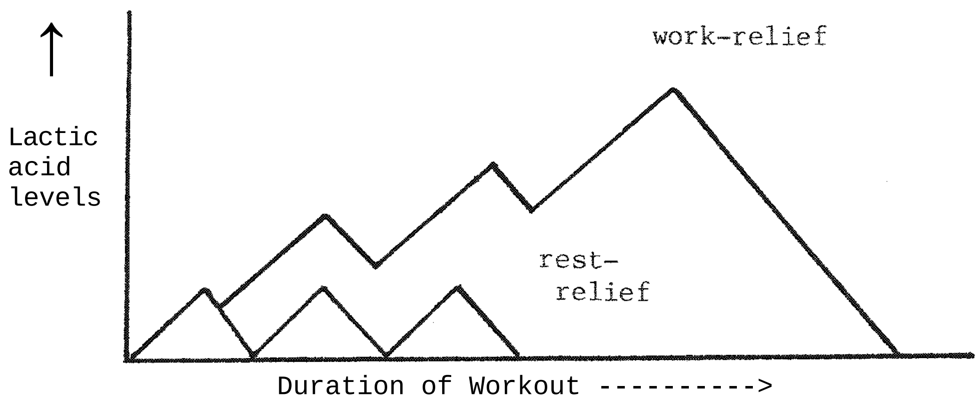
Scientifically, the length of the interval and the type of activity that goes on during it are aimed specifically at controlling the recovery of the ATP-CP system. By controlling the recovery of the ATP-CP system, one can help determine which energy system is emphasized during the workout. The following table shows the percent of ATP-CP restored according to the duration of rest.

Duration Of Rest Interval	Percent Of ATP-CP Restored
Under 10 secs.	very little
" 30 "	50%
" 60 "	75
" 90 "	88
" 120 "	95
" 180 "	99

If one wishes to emphasize the ATP-CP system, long rest intervals are indicated because they allow for a complete replenishment of ATP-CP. The rest should be complete rest, no activity except stretching, easy paddling and so on,

To emphasize the LA system in the rest interval, there are two ways, one more extreme and exhausting than the other. In the first, the rest period is 2-3 times or more of the work period and the recovery is complete. In slalom this would typically be 90 second courses with an easy paddle back to the start. The result of this method is to dissipate lactic acid so that the body is ready for another intense effort.

In the second method, however, the rest is short (say, half the work period), and involves medium intensity work. This kind of rest interval is called "work-relief". It partially blocks restoration of ATP-CP, thus meaning that the next interval will be undertaken with the LA system. The following graph shows how this works:



As can be seen above, with work-relief, each new work interval is undertaken at higher lactic acid levels, so that at the end of the workout, the level is very high and the boater has to work with higher amounts of lactic acid than he does with rest-relief.

The reader may well ask, "If the recovery is incomplete, how can the next interval be done at the highest possible intensity?" This brings us to an important concept: Intensity regarding the LA system means intensity RELATIVE TO YOUR CAPACITY at the time of exertion, not just relative to your absolute maximum. A slalom workout highly stressing the LA system would be: 7 X 120" at all out intensity, with a work-relief rest interval consisting of a fast paddle back to the start. Because of the work-relief intervals, the work during the work interval is even more lactic than it would be with complete rest. These are very exhausting workouts and cannot be repeated every day.

To target the 02 system, the rest interval should be short because there has been neither great depletion of ATP-CP nor great build-up of lactic acid in lower intensity work, Furthermore, the rest interval should be complete rest, since a work-relief interval might produce lactic acid and thus make the next interval emphasize the LA system more.

NUMBER OF REPETITIONS/SETS: What is presented here are the levels for elite paddlers. The reader must understand that there is a great deal of difference between what the World Champion can and should attempt in training and what an intermediate should attempt. Training books in many sports often forget to point this out, with the result that some people try to do too much too soon. With that in mind, the levels here are targets to work up to over many years of training, not levels to jump into.

There are various theories for constructing the proper number of repetitions and sets for interval training, based largely on running. But since in my experience they do not correspond all that closely to what I have personally observed World Champions in all classes doing when performing interval training, I have elected to simply present here what they do instead of trying to explain the theories. (I'm not sure I understand some of them, anyway!) The following table shows this. As the reader can see, by multiplying the number of "Reps. per Workout" times the "Secs. Rep. Time," the total amount of work performed in a workout goes up the longer the work interval is. Thus, if an elite paddler is doing full length courses, he or she will typically do up to 2.5 times as much total work as when doing 15-second courses.

Sets are groups of repetitions. The purpose of sets is simply to break up the total number of repetitions with a longer rest interval before starting the next set of repetitions. This added rest allows

Guidelines for Constructing Interval Workouts
In Whitewater Gates
(Based on World Champions in All Classes)

System Emphasized	Secs. Rep. Time	Reps. per Workout	Sets per Workout	Reps. per Set	Work: Rest	Type of Rest
1. ATP-CP	15	35	5	7	1:3	Rest-Relief (easy paddling, stretching)
2. ATP-CP/ LA	30	25	5	5	1:3*	Work-Relief (light to medium paddling)
	60-70	15	3	5		
3. LA/02	90	12	3	4	1:2*	Work-Relief
	120	8	1	8		
	160	5-10**	1	5-10		
	180	5-8**	1	5-8		
	200	5-8**	1	5-8		
4. 02	240	5-7**	1	5-7	1:1/2*	Rest-Relief
	480	4	1	4		
	900	2	2	1		

* These are also done as repeats with long rest-relief intervals.

** K1Ws, C2s, and C2Ms tend to be at the lower end, while C1s and K1s tend to fall at the higher end.

N.B. This table is based on class I-II water. In bigger water, all of the figures have to be reduced significantly because the work is much harder.

for more intensive work during work intervals. The set concept works particularly well for slalom workouts because each set can be a new course (although it doesn't have to be), and the rest interval between sets is used to design a new course.

Determining the frequency of interval workouts has to be done by each individual. There are so many factors that enter into it that I find it impossible to generalize. It depends on how experienced the boater is, what time of year it is, how many total workouts the boater is doing during that period, and a host of other things. In general, however, it is typical that with each successive year, the frequency will increase --as will the number of repetitions. Basically, the boater should strive to do as much as he can, but still recover from it. 'Checking the pulse rate every morning is one way to tell. If it is five or six beats above normal, then that is a strong indicator that the boater has not fully recovered and that he should not do a hard workout until the pulse comes down.

REPEATS: Repeats are similar to interval training except that there is longer rest and complete recovery between each bout of work. Thus, each work period is at very high intensity. Running a full-length whitewater course in training sessions is a good example. A typical session might be 7 X 220" with the rest period between repetitions equal to the carry back to the start, i.e. 20 minutes. I have found that repeats are particularly good for building consistency and thus I use them a great deal in training sessions.

PROGRESSIVE OVERLOAD: Gradually increasing the number and intensity of intervals is the aim of training. This can be done by 1) doing each slalom course faster; 2) cutting down on the rest period; 3) doing more runs and/or courses in the workout or 4) a combination of the three. One way to decide when to increase the intensity is to check the post-exercise heart rate. The rate is taken 90 seconds after the last run of the workout. A lower heart rate following several identical workouts means that it is time to increase the intensity.

Discussion

It is important to understand the interrelationship between the five variables which make up interval training. By not ensuring proper intensity or proper rest, the wrong energy system might be emphasized. For example, if the aim is to emphasize the ATP-CP system, 15 second courses at maximum intensity, followed by 45-60 seconds is best. This will allow the system to be used over and over again at maximum intensity. If on the other hand, one were to do 15 second all-out gate sprints with only 15-20 seconds rest, the work would become more lactic, because there would be ever increasing amounts of lactic acid in the muscles.

To target the LA system, one good way would be through sub-maximal intensity 30-90 second courses, followed by 2-5 minutes rest. But if the intensity level is too low, there is no development of the LA system, while there might be some development of the 0_2 system.

To emphasize the 02 system one good way might be 8 minute intervals of high intensity with 2 minutes of rest. But if the intervals were shorter, say 3-4 minutes and of sub-maximal intensity, the work would be more anaerobic, although the courses would be too long for it to be completely anaerobic.

There can also be problems in misusing the number of repetitions or the frequency of interval workouts. If the intensity is increased too fast, an overtraining effect might occur and the boater is forced to take a lot of time off in order to recover.

Thus, while it is easy to make mistakes in arranging all the variables in interval training and wind up emphasizing a system you did not intend to, it is also possible to do combination workouts in which two or more systems are worked in the same workout, indeed the same interval. Since slalom is really a combination of the three energy systems, combination workouts are often a very good idea.

Examples might be:

* 10 X 15" at 100% with 45" rest (ATP-CP); 5 X 120" at 90% with 240" rest (LA system).

* 10 X 120" at 90% with long rest-repeats (LA and 02 systems).

* Pyramid sprints on flatwater: 100, 200, 300, 400 meters and back down again (all systems).

MUSCLE

Slalom paddling involves the use of endurance (slow-twitch) muscle fiber and power (fast-twitch) muscle fiber. Paddlers should be sure that in their training they develop both. Some individuals, because they are born with a higher proportion of one kind than another, tend unwittingly to stress that kind in their training and neglect the development of the other. In this case, they have a deficiency for slalom purposes.

Slow Twitch -- Fast Twitch

It is muscle development combined with cardiovascular conditioning which permits the intensity and volume of training necessary to maximize the body's responses to training. If muscles are not sufficiently developed, the athlete cannot sustain a high enough workload to stimulate the energy systems adequately.

There are two main types of skeletal muscle fiber, an endurance type, called "slow twitch" and a speed and power type, called "fast twitch." There are actually two sub-types of fast twitch fiber as well; fast twitch A, a slow-fatiguing fast-twitch fiber; and fast twitch B, a fast-fatiguing fast-twitch fiber.

Slow-twitch muscle fiber requires a steady supply of oxygen, storing it for the onset of work but quickly requiring its replenishment from outside air. These fibers are very resistant to fatigue, having access to the oxygen supply through a highly developed network of capillaries.

While slow-twitch fibers are suited for endurance tasks, fast-twitch fibers may be called upon instantly for speed and power without having to wait several minutes for the oxygen supply to be replenished from the outside air. Weight training and high intensity training increases the size of these fibers and their ability to break down glycogen, and use it to do work. The more fast-twitch fibers an athlete has, the quicker he may fatigue, being able to work at top speed for only the short time that is required of him in his event.

At birth each individual is endowed with a certain proportion of each fiber, thus giving some people greater potential to become power athletes, such as sprinters, and other people greater potential to become endurance athletes, such as marathoners.

Unfortunately, there are two factors that complicate the discussion of fast-twitch and slow-twitch fibers:

* It is hard to determine accurately what proportion of each an individual has. In the first place, different muscles within the same person have different proportions. Thus, if we are talking about the application to paddling, testing the leg muscles is not going to help. Secondly, different areas within the same muscles have different proportions and thus several samples have to be taken from the same muscle in order to get an accurate reading. Since this involves taking a little "bite" (muscle biopsy) out of the muscle several times, most athletes, understandably, are reluctant to permit it.

* While an individual may be born with a certain proportion of fast-twitch fibers, training can "bend" the fibers somewhat, especially in making fast twitch fibers function more like endurance fibers. Long duration paddles at high intensity can do this.

In my view, a slalom race consists of both endurance and power components. Endurance (in slalom terms), is simply the ability to get down the course without becoming so tired that you slow way down, hit gates or make bad time errors. Power comes into play in things like accelerating the boat at crucial points, or making bow sweeps or reverse sweeps.

Continuous long distance paddles in gates improve the function of slow-twitch fibers and improve endurance. Many paddlers use the downriver boat for endurance paddles but while this certainly improves endurance in a straight line, it is not specific enough for maximum improvement in gate running endurance. This is simply because different muscles are used in running the gates than in simply paddling straight ahead.

Furthermore, if all the paddling is done at slow speeds, muscular power typically diminishes over time. This is because the slow paddling does not activate the fast twitch fibers and the fibers lose some of their capacity for speed through disuse. Power training will prevent this.

When most people hear the term "power training" they think of weights because this has traditionally been the method for developing power. But it should be borne in mind that weight lifting may not simulate the actual motion of the joints and limbs as used in slalom paddling, and strength developed in one particular joint motion will not transfer to other joint motions. Also, heavy lifting seems to develop a non-explosive power. In my opinion, all of this argues in favor of short gate sprints for developing power for slalom. The moves are highly specific this way.

However, if one wishes to do the power training with weights, the following points should be borne in mind:

* Make the lifts as specific to slalom movements as possible.

* Select a moderate weight which allows you to move as fast or faster than you would in competition.

* Before each repetition, the joint to be strengthened should not be stretched to increase the amount of force produced and developed. If a muscle is stretched, it contracts with greater force. Stretch receptors in the muscles and tendons produce what is called the "stretch reflex." But since the use of the stretch reflex does not promote pure strength work -- it supplies "free" work -- it is a form of cheating and should be avoided.

* Try to vary the grip or plane of movement in the weight exercise. Slalom paddling in gates involves significant variation: a forward stroke might be done with the arms very close to the body (if the boat is too close to the gate), or quite far from the body (if the boater is leaning hard to his on-side, for example). Simply developing strength in one plane of movement does not improve strength to the maximum extent in the alternate positions.

* Begin with adequate warm-ups so that the risk of injury is minimized. Most of the injuries that I know of among slalom paddlers come from weight workouts, not boat workouts.

Paddle Relaxed

The ability to relax while paddling a slalom course is one sign of a top boater. If muscle coordination is very high, the boater finds it easier to relax during paddling and thus lowers his energy costs even more. Therefore, two points to think about in training and racing:

* Reduce tension in all muscles not directly involved in moving the arms, back and trunk. For example, head movements and shoulder hunching, facial grimaces and so on should be eliminated.

* Practice paddling at a given pace with as little energy as possible.

Muscle Elasticity

It is the timing of muscle forces which distinguishes the good paddler from the really excellent one. Precise timing of back, torso twist, arm and hand movements allow the paddler to make use of the elasticity inherent in muscle tissue. Because a stretched muscle automatically rebounds to its resting length, it has the capacity to do "free" work and so increases the force, power, and efficiency of your movements. Some experts think this elasticity can account for half the total energy used to do work.

Upstream gates are one example. If the paddler can put his entry draw stroke quite far in front of him, he is able to exert a stronger pull on it when he converts it into a forward stroke to pull himself higher into the gate.

Repetitive work, like paddling forward, is performed at a cadence which the individual feels is the most comfortable or efficient. He chooses the cadence probably because of muscle elasticity. If he moves too slowly, certain muscles must contract isometrically to prevent this elastic force from acting. As a result, a slow paddle may become more fatiguing to him than a faster one, even though the total work is reduced. Effective use of muscle elasticity requires that he moves at some minimum speed.

Warm-up/Warm-down

Adequate warm-up before paddling reduces the resistance of muscle and connective tissue to joint movements since, with increased temperature, cellular tissues become more pliable. Warming up also prepares muscle for work by supplying it with more blood and oxygen. Warmth also accelerates the speed of the chemical reactions responsible for liberating energy from within the muscle. Without a warm-up, the muscles are shocked into sudden, vigorous exertion without an adequate oxygen supply. This forces the muscle to furnish much of the energy anaerobically for the first one or two minutes. An oxygen debt is created along with the production of a small but perceptible amount of lactic acid. This oxygen debt will be repaid in the ensuing minutes of exercise and result in the oxidization of the lactic acid. This process requires more energy than if a smaller oxygen debt was formed during the warm-up. Thus, warm-up enhances performance as well as decreasing the likelihood of injury, an important point for the older athlete, whose connective tissue and joint structure is no longer supple.

Adequate warm-down is equally important because it helps to dissipate lactic acid built up in the exercising muscle and bloodstream during a training session, and thus accelerates recuperation before the next session. Furthermore, warm-down also stretches the muscles that have been used. Paddling is a repetitive activity which may cause stiffness in joints and muscle tightness. For this reason, particularly after a long session, there should be some light paddling and stretching to restore flexibility to the paddling muscles including the : latissimus, trapezius, deltoids, pectorals, biceps, triceps, forearms, and hamstrings for Kls; trunk muscles and hip flexors for C1s.

A warm shower facilitates this warm-down and stretching, but unfortunately, it is often difficult for paddlers coming off the river to get to a shower very quickly. However, changing into warm, dry clothes is a reasonable substitute.